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Magnetic and Ionospheric Storms*.

By

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With 4 figures.

Summary. The characteristic ionospheric storm variation of F_2 Layer ionisation at a temperate latitude station is described and compared with corresponding effects at other latitudes. The well known marked variability of the F_2 Layer critical frequency is attributed, in part, to the operation of the ionospheric storm mechanism. The lack of correlation between variations of F_2 ionisation at two sites, at a considerable distance apart, is due to the fact that ionospheric storm manifestation is found to vary, in sign and magnitude, with geomagnetic latitude, and is also subject to a diurnal control determined by local time.

Zusammenfassung. Die charakteristische Ionosphärensturmvariation der Ionisation der F_2-Schicht an einer Station der gemäßigten Breite wird beschrieben und mit entsprechenden Vorgängen in anderen Breiten verglichen. Die bekannte eindeutige Veränderlichkeit der kritischen Frequenz der F_2-Schicht wird teilweise der Wirkung des Mechanismus der Ionosphärenstürme zugeschrieben. Das Fehlen einer Korrelation zwischen den Variationen der F_2-Schicht an zwei in beträchtlicher Entfernung voneinander gelegenen Orten erklärt sich aus der Tatsache, daß das Auftreten der Ionosphärenstürme nach Vorzeichen und Ausmaß mit der geomagnetischen Breite variiert und außerdem einem ortszeitlich bedingten Tageseinfluß unterliegt.

Résumé. On décrit la variation caractéristique d'ionisation de la couche F_2 lors des tempêtes ionosphériques observées à une station de latitude moyenne et on la compare aux phénomènes analogues à d'autres latitudes. La variabilité marquée et bien connue de la fréquence critique de la couche F_2 est partiellement attribuée au mécanisme des tempêtes ionosphériques. L'absence de corrélation entre les variations de la couche F_2 en deux endroits considérablement éloignés l'un de l'autre s'explique par le fait que l'apparition des tempêtes ionosphériques varie en signe et en intensité avec la latitude

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* Dedicated to Professor Dr. H. Benndorf on the occasion of his eightieth birthday.

géomagnétique et présente en outre une périodicité diurne dépendant de l'heure locale.

1. Introductory.

In my tribute article to Professor Dr. H. BENNDORF, on the occasion of his 80th birthday, I propose to discuss a problem in the field of atmospheric physics, a subject to the progress of which he has himself made such signal contributions.

Although the existence of the ionosphere was first established as far back as a quarter of a century ago, it is only in recent years that the detailed nature of its regular and irregular variations has become clear. Such information has emerged largely from the systematic hourly radio soundings of the ionosphere conducted at various observatories. In Britain such systematic observations were begun in 1930, and, in 1932, it was decided to send a radio expedition to Tromsö (lat. 69,6° N; long. 18,9° E), in North Norway, to study, by the same methods, the relation between ionospheric conditions and polar phenomena. It was at once found at Tromsö that there was an intimate connection between magnetic storminess and ionospheric perturbations. In the case of the severe storms, strong absorption of the exploring radio waves was encountered, often temporarily preceded by the appearance of abnormal E Layer ionisation. Under such conditions it was impossible to observe the characteristics of the F_2 Layer. With less severe storms, however, depressions of the F_2 Layer critical frequency were observed.

In the present article the study of ionospheric and magnetic storms is continued by an exposition of results for temperate latitudes and other stations.

2. The Characteristic Trend of an Ionospheric Storm in Temperate Latitudes.

In order to demonstrate the characteristic trend of an ionospheric storm the "super-posed epoch" method has been used for a number of storms experienced at Slough (lat. 51,5° N; long. 0,6° W) in South-East England. For this purpose days of major depressions of the F_2 Layer critical frequency (fF_2), associated with geomagnetic storm conditions were taken as zero days, and the noon and midnight critical frequencies (f), expressed as fractions of the appropriate monthly mean values ($\bar{f}$), extracted both for the zero day and for a number of days before and after. The average results obtained are exhibited by the continuous curve of Figure 1. Here it will be seen that there is a tendency for the critical frequency to be slightly above the average (i. e. $(f/\bar{f}) > 1$) during the period immediately before that of the major depression. Also it is seen that, after the major depression, the recovery to normality is slow.

It is of interest to compare the characteristic variation of the F_2 Layer critical frequency during ionospheric storms with the concomitant variations of terrestrial magnetism. For that purpose the Abinger K

figures of magnetic storminess were treated for the same periods by the same super-posed epoch method. The characteristic average variation of geomagnetic storminess, as expressed by K figures in this way, is also shown in Figure 1 as a broken line. We can therefore compare on this diagram the characteristic trends of both magnetic and ionospheric storms, and note, for example, that the maximum of magnetic storminess occurs more than 12 hours earlier than the maximum phase of the ionospheric storm.

This particular result has been given precision in another way. The daily noon values of fF_2 at Slough for the 59 days in February and March 1949 have been compared with a) the Abinger noon K figures for the days in question, b) the average Abinger K figures for the period 00,00 to 12,00 h. of the days in question, c) the average Abinger K figures for the period 12,00 to 24,00 h. of the previous day, and d) the average Abinger K figures for the period 00,00 to 12,00 h. of the preceding day. Correlation factors were calculated in each of the four cases and the results are set out in Table 1.

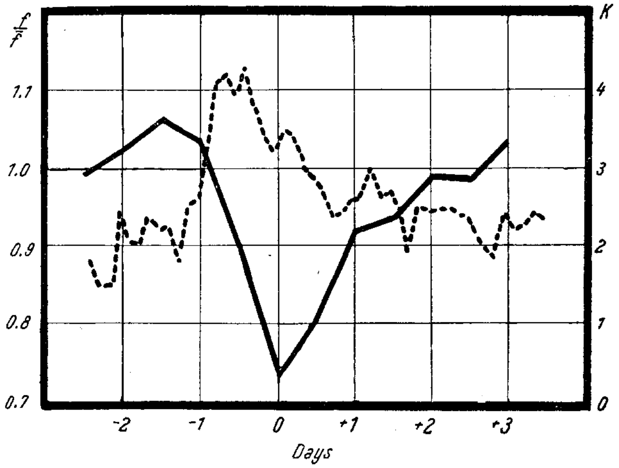

Fig. 1. Characteristic variations of relative critical frequencies ($f/\bar{f}$) and K magnetic indices during ionospheric storms.
——— $f/\bar{f}$; - - - - - - K index.

Table 1.

fF_2: Time of measurement	K Figure: Time of measurement	Correlation Coefficient
noon	noon	— 0,063 ± 0,08
noon	00,00 to 12,00 h., same day	— 0,34 ± 0,08
noon	12,00 to 24,00 h., previous day	— 0,41 ± 0,07
noon	00,00 to 12,00 h., previous day	— 0,095 ± 0,08

Here it will be seen that a definite inverse correlation is obtained when the noon values of fF_2 are compared with the K figure for the twenty four hours preceding the period of ionospheric measurement. Thus it would appear that the depression of fF_2 in an ionospheric storm is a consequence, rather than the simultaneous accompaniment, of magnetic activity.

The inverse correlation between the Slough noon values of fF_2 and the K figures for the period 12,00 to 24,00 h. of the preceding day is illustrated in Figure 2 where both quantities are plotted for the days of the months of February and March 1949.

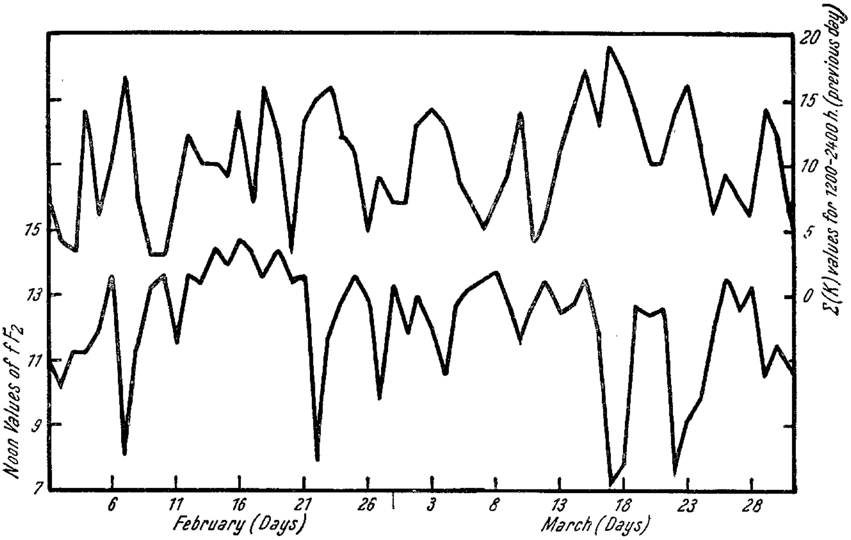

Fig. 2. Lower curve: Variation of noon values of fF_2 at Slough during February and March 1949; Upper curve: Sums of K magnetic figures for period 12,00—24,00 h. on the previous days.

The results of this section are in agreement with those previously obtained by L. HARANG [*1*], who, working before magnetic K figures were available, compared noon values of fF_2 with International Magnetic Character C Figures (whole day). He found a more marked negative correlation when the C figures selected were for the day previous to the ionospheric measurement than when the C figures related to the day of the ionospheric measurement.

3. Further Ionospheric Storm results in Temperate Latitudes.

In a recently published account [*2*] of a world morphological study of ionospheric storms, W. R. PIGGOTT and the writer have shown that, at temperate latitude stations, it is usual for a storm to have a short positive phase (i. e. $\Delta fF_2 > 0$) preceding the longer negative phase (i. e. $\Delta fF_2 < 0$). It has also been shown that most remarkable brief ionospheric changes are often found to accompany "sudden-commencement" magnetic disturbances. On such occasions a rapid depression of fF_2 occurs, followed immediately by a short positive phase. Such events are often not recorded in the normal hourly routine ionospheric measurements since they usually only last about half an hour.

A seasonal variation of ionospheric sensitivity to ionospheric disturbance has also been noted at Slough. In summer, when the F Layer is markedly bifurcated into its F_1 and F_2 components, the tendency for fF_2 to be depressed in ionospheric storms is greater than in the winter months when positive phases tend to be more frequent. On a few occasions, only positive phases have been noted e. g. during the great geomagnetic storm of February 7 and 8, 1946.

4. The World Morphology of Ionospheric Storms.

At auroral stations it is usual for magnetic storms to be accompanied by negative ionospheric storm phases only. At temperate latitude stations the bi-phase sequence, as described above, is experienced. On the other hand, near the equator it is more usual for only positive phases to be experienced. However, in the case of one or two magnetic storms of exceptional severity, negative phases have been experienced even on the equator.

The above remarks refer to the variation of storm manifestation with latitude and here it may be mentioned that it is magnetic latitude which is of significance in this connection.

From the detailed study of ionospheric storms at both Slough and at Washington (lat. 39° N; long. 77,5° W) it has become clear that ionospheric storm departures from normality are subject to a marked diurnal control. At both stations it is found that, in the case of negative phases, the most marked proportional reduction of ionisation in the F_2 Layer is experienced round about local noon. This fact is well illustrated in Figure 1. The strong diurnal control of ionospheric storm manifestations can also be well illustrated in the results obtained by O. Burkard [*3*] who has collected all the fF_2 data from 30 ionospheric stations for the magnetic storm of 14th to 16th March 1948. From these results it can clearly be seen that ionospheric storm results for stations on the same longitude can be correlated, but that, in order to correlate results at stations on the same latitude but on different longitudes, allowance must be made for the differences in local time.

5. The Influence of Ionospheric Storminess on F_2 Layer Variability.

It is well known that the value of fF_2 is subject to great day-to-day variability and it has been suggested by W. R. Piggott and the author [*2*] that this variability is due, to a considerable extent, to the operation of the ionospheric storm mechanism. When fF_2 measurements are made at stations fairly close together, a remarkably good correlation between the two series is found. As tested in this way the F_2 Layer may be said to be uniform over a distance of a few hundred miles. For two stations

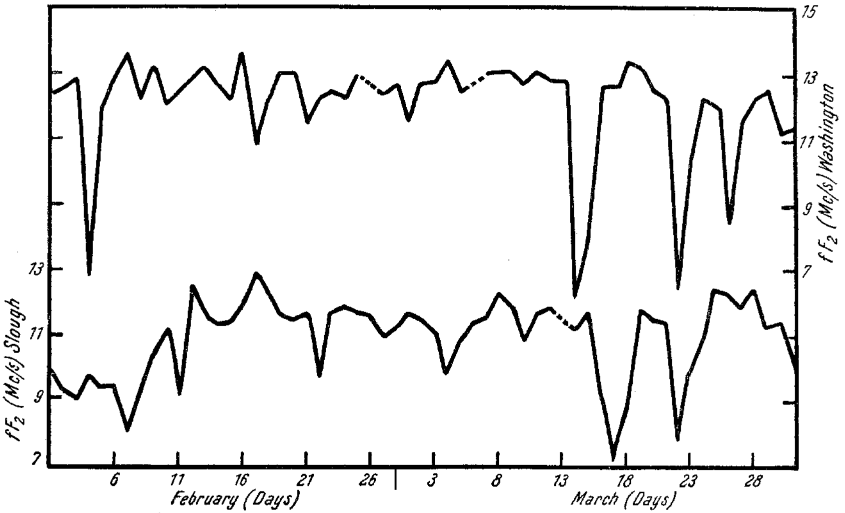

Fig. 3. Comparison of daily fF_2 values at Washington (above) and Slough (below) each day at 17,00 h. G. M. T. during February and March 1949.

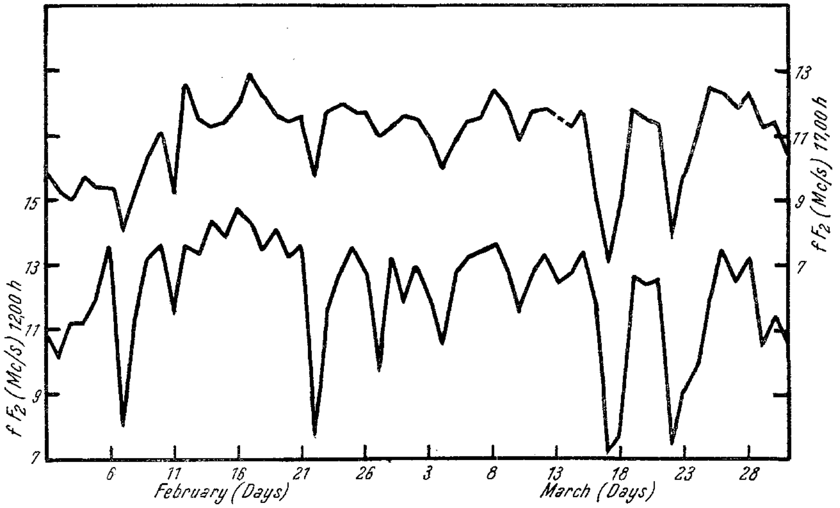

Fig. 4. Comparison of values of fF_2 (Slough) at 12,00 h. (lower) and 17,00 h. (upper) G. M. T., for each day in February and March 1949.

separated by much greater distances there is usually very little correlation except in the case of large ionospheric storms which last for some days.

This lack of day-to-day correlation is especially noticeable between two stations of different longitude. It is illustrated in Figure 3 where measurements of fF_2, made simultaneously at 17,00 G. M. T. at Slough and at Washington during February and March 1945, are exhibited together. No marked correlation is noted except in the case of the ionospheric storm which occurred on March 22nd. Here it may be noted that two curves in which the Slough values at both noon and at 17,00 G. M. T. are plotted together, are closely similar. This is illustrated in Figure 4. It is therefore the difference in longitude which is responsible for the lack of correlation between the fF_2 values for Washington and Slough.

References.

1. HARANG, L: Gerlands Beitr. Geophysik **46,** 438 (1936).
2. APPLETON, E. V., and W. R. PIGGOTT: Nature **165,** 130, Jan. 28 (1950).
3. BURKARD, O.: Arch. Met., Geoph. Biokl., A **2,** 315 (1950).